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The induction probe utilization to the metal commutator geometry detecting

POWER ENGINEERING

ABSTRACT

The electrical commutator motors are steel very often used machines for many applications. The advantages of this motors are cost index value, easy speed regulation and dimensions. The disadvantage is the short lifetime and service period of the sliding contact of the motor. Usually the sliding contact service period set the motor service period. The brush, brush holder and the commutator (slip-ring) are created the sliding contact. The commutator surface quality influents on sliding contact lifetime, too. Therefore the measurement workstation has been developed on our department. Measurement workstation has two main parts. The first part is table including the device, the motive machine sources and the measuring probe movement controls. The measuring frame is the second part. The measurement device including the measuring probes, the IR speed sensor, the data logger, the digital oscilloscope and personal computer with GPIB control card and Labview software. The motive device is assembly of the regulated supply and the motor. The induction analog probes are used for low distance sensing between the probe tip and electrically conducting materials.

I. GENERATION OF THE MEASURING WORKSTATION FOR SENSING OF THE COMMUTATOR SURFACE

Till now the commutator surface has been measured with the contact measured method, based in induction sensor. The rotor of the machine rotates with low speed. The probe tip is mechanically connected with ferrite core. The moving of the ferrite core changes of the impedance and the magnetic flow and induced voltage. The voltage gives the deflection of the final measuring device.

The first measuring workstation was developed in 1988 on KESP VUT in Brno. The workstation has been developed for the contactless measurement of the commutator surface in dynamic state. The workstation utilises the probe composed of the exciting coil and detecting coil. Measuring probe allows the contactless measurement of the distance of the electrical conducting objects. The exciting coil is supplied through the harmonics high-frequency current. Detecting coil is placed as near as possible over the surface. The detecting coil has low mutual coeficient with the exciting coil.

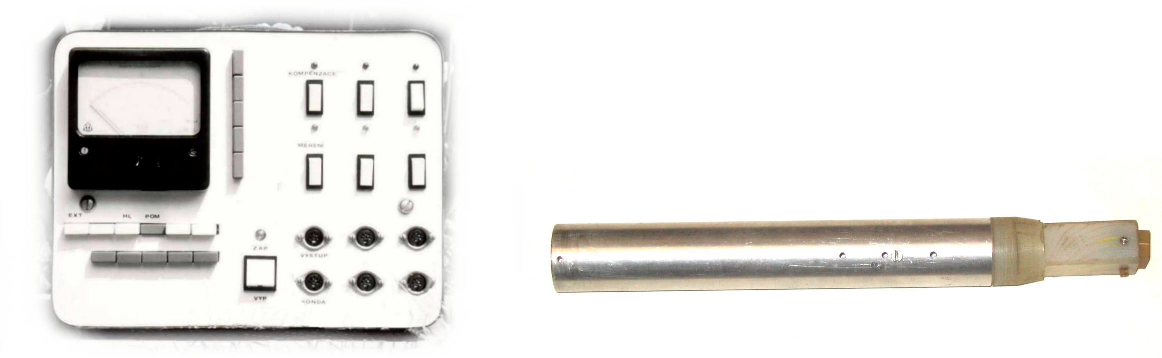


Fig.1: The datalogger and the probe of the 1. generation measuring device
Legend: a) datalogger, b) probe

The induced voltage is affected by the eddy currents in the measured object. Therefore the induced voltage is equal to distance from the measuring object. The probe is in the fig.1.

The basic part is oscillator connected to the measuring probe and the detector. This generation has error of the measurement about 15 um. All measurement has a long time for evaluation of the results. Therefore the parts of the measuring workstation have been developed.

III. GENERATION OF THE MEASURING WORKSTATION FOR SENSING OF THE COMMUTATOR SURFACE

The way of the measurement of the commutator bars protrusion has been changed in this generation of the workstation. The new measuring devices and the new electronic components allow this change of the measurement. The measurement resolution has increased.

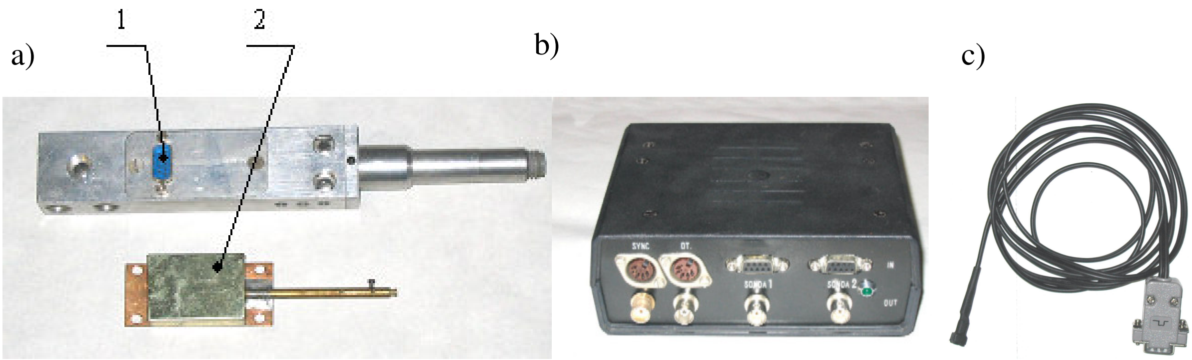


Fig.2: The parts of the measuring device.
Legend: a) measuring probe (1 – III.generation, 2 - IV.generation), b) datalogger, c) speed sensor

The evaluation of the output signal is in the digital form. The digital oscilloscope Tektronix TDS210 has function as an analog-digital converter. The waveform from the screen of the scope has been stopped and has been transferred to the PC via GPIB bus. The signal is upload to the PC with developing program LabView. This software is intended to developing control and measure programs. Labview was used just for waveform upload in this generation. The next evaluation and analysis has been made in MS Excel. The evaluation of the results takes a long time, it isn't optimal. In [3] has been published drive composed of the step-motor and the gear.

This drive has been assembled to the workstation frame for the movement of the probes. This improvement set up faster and more accurate positioning of the measuring probes. The accurate movement of the probes is used for the measurement of the transform characteristics of the probes. The transform characteristics define the dependency between the output probe voltage and the distance from the measured object. In this workstation the induction speed sensor has been replaced by the IR optical reflective sensor.

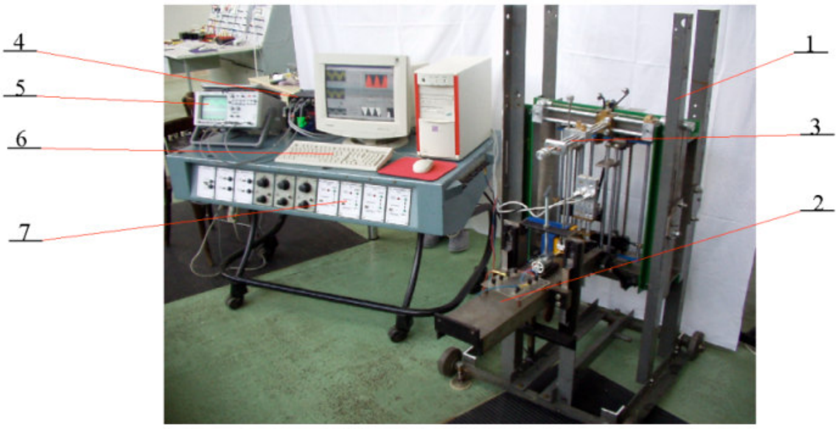


Fig.3: Front view of the measurement workstation
Legend: 1 – workstation frame, 2 –holder of the measured machine, 3 – moving part, 4 – datalogger and step-motor control unit, 5 – digital oscilloscope, 6 –PC with LabView,7-control button for moving part .

IV. GENERATION OF THE MEASURING WORKSTATION FOR SENSING OF THE COMMUTATOR SURFACE

The few new things have been done in this generation. The most important is development of the new probes. The probes has only one measuring coil. The probes has digital signal transfer between datalogger and probe. The probes have higher level of protection against electromagnetic interference. All uploading and evaluating procedures have been made in the LabView. This new program brings upload and evaluation at a time. The new procedure for transfer characteristics interleaving by polynomial function has been developed. This innovations have been published in [1].

Tab.1: Comparison of the parameters of the workstation generations

Generation	Tip length [mm]	cross-section of probe tip [mm]	Probe resolution [µm/mV]	Measuring error [µm]
I. generation	300	17x20	10	15
II. generation	150	∅ 10	5	12
III. generation	150	∅ 10	2	6
IV. generation	100	∅ 3	0,5	3

WORKSTATION DESCRIPTION

Measurement workstation has two main parts. The table with the devices, with the motive machine supply and with the measuring probe position controls are the first part. The measuring frame is the second. It is in fig.3. The measurement device is composed of the measuring probes, the IR speed sensor, the datalogger, the digital oscilloscope and PC with GPIB control card and software. The electrical supply and the motor create the motive device, or the motor is running itself. The torque transfer from the motive electrical machine to the measured commutator machine secures the flexible clutch. Some high-speed machine or high-speed air turbine could be used for high speed testing. The developed induction analog probes are used for the low distance sensing between the probe tip and electric conducting materials. The probes are based on the changes in the resonance circuit. The changes are provided by different distance of measuring coil from measured object. The analog induction probes have DC output voltage equal to the distance between probe tip and the sensing surface. The transfer function is the mathematical polynomial function for conversion from DC output voltage to the distance. The probes are placed on support. The support movement secure the step motor, electronic control circuits and gearbox. The rotational movement transfer to translation movement is provided by the worm drive. The probe output voltage is the prime information about the distance. The two measured induction probes could be used for measurement, in fig.4. One probe measure distance from the slip-ring or the commutator. The second probe measures vibration of the measuring object and probe is fixed together with the first probe. This method allows the elimination of the vibration from the measurement. The signal transfer between the datalogger and the probe is digital. The data-logger adjusts the probe signal to digital oscilloscope level. The data-logger transfers the IR speed sensor signal to oscilloscope too. This signal is used to waveform synchronization on the scope display. The digital form of the measured waveform is transfer to the PC. The program for this measurement is developed in the LabView. The program imports data from the oscilloscope and analyses the waveform. The Labview has a wide range of functions for mathematics operation and for waveform analysis, for the I/O communication and many others. The program allows the printing, saving the data and opening of the saved data.

The measured voltage waveform is converted to the distance utilizing the transfer function of the probes. The peak of the measured waveform is equal to the bars. The evaluation function calculates the discrete protrusion of the commutator bars and the waveform of the bars protrusion is shown in fig.6. The most protrude bar is represented by zero value. The difference between the maximal protruded point of the surface and the minimal protruded point of the surface specifies the ovality of the commutator.

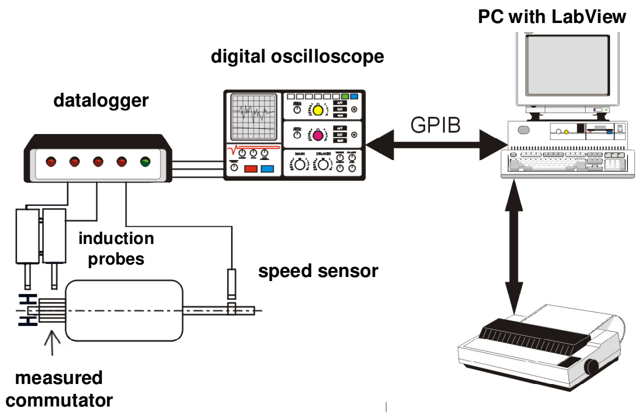


Fig.4: The block scheme of the measuring workstation for low distance sensing.

First have been measured the slip-ring of the car alternator. The results of the contact and contactless measurement is in the fig.5. The contactless measurement is provide with error up to 1μm. This measurement shows that our contactless measuring method is acceptable for detecting of the shape of the slip-ring in the dynamic state. The ovality of this slip-ring is over the limits and it can influences the lifetime of the slip-ring.

a) b)

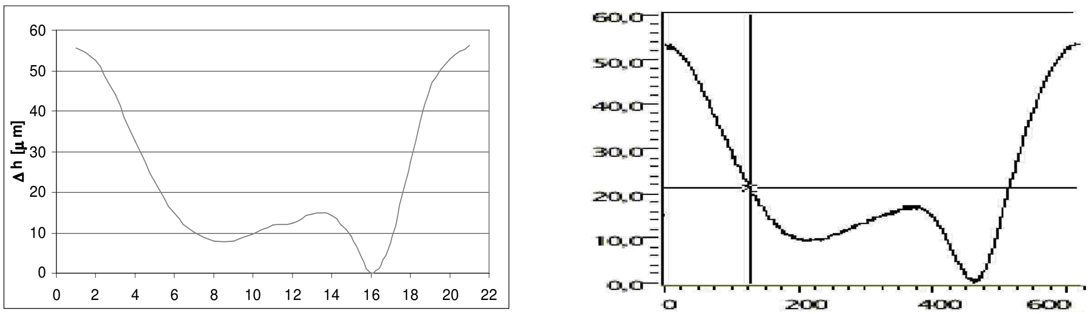
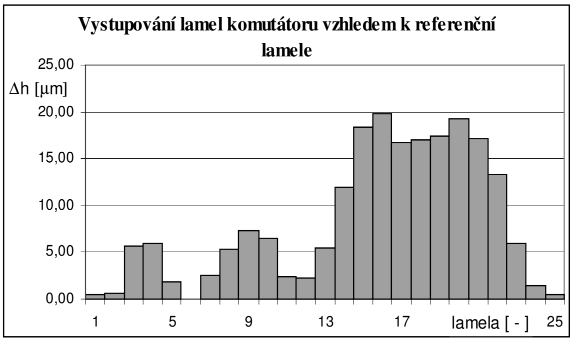


Fig. 5: Waveform of the roundness of the slip-ring:
a) measured with contact probe
b) measured with contactless probe of our construction (3000rpm)

The next was commutator with 24 cooper bars and diameter 28mm. The quality of the commutator has been measured on the machine. The type of the machine is a universal commutator machine designed for use in vacuum-cleaners. The machine has ran for 200 hours before measurement. The measurement has been provided up to nominal speed 27000rpm. The vibration of the machine has been measured and has been eliminated from the measurement. The results of the contact and contactless method is in fig.6. The protrusion of the bars of the commutator is over the recommended value.

a) b)



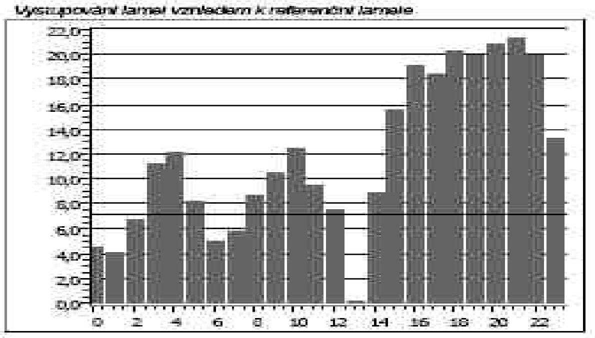


Fig.6: The universal commutator machine bars protrusion.
a) measured with contact probe
b) measured with contactless probe of our construction n=24000 rpm.

The example of the error evaluation for the measurement of the slip-ring. The evaluation is made of three measured values.

- average value

$$\overline{q} = \frac{1}{n}\sum_{k=1}^{n} q_k = \frac{1}{3}\sum_{k=1}^{3} q_k = 60{,}46\ \mu m \tag{1}$$

- standard deviation

$$s^2(\overline{q}) = \frac{1}{n-1}\sum_{k=1}^{n}(q_k - \overline{q})^2 = \frac{1}{3-1}\sum_{k=1}^{3}(q_k - 60{,}46)^2 = 0{,}58\mu m \tag{2}$$

- uncertainty type uA

$$u_A^2 \approx s^2(\overline{q}) \Rightarrow u_A = \sqrt{\frac{s^2(\overline{q})}{n}} = \sqrt{\frac{0{,}58}{3}} = 0{,}44\mu m \tag{3}$$

- uncertainty type uB

$$u^2{}_B = \frac{(a_+ - a_-)^2}{12} = \frac{(62-58)^2}{12} = 1{,}33 \quad \Rightarrow u_B = 1{,}15\mu m \tag{4}$$

- combined uncertainty uC

$$u_C = \sqrt{u_A^2 + u_B^2} = \sqrt{0{,}44^2 + 1{,}15^2} = 1{,}23\mu m \tag{5}$$

The result of the measurement of the slip-ring is 60,46 ±1,23µm. The result of the measurement of the standstill slip-ring using contact method is 52 µm. The measuring error can be the difference between result of the contact measurement and the result of the contactless measurement. This error is composed of the error of the transformation characteristic, of the vibration of the running slip-ring and other influences.

Conclusion

There is shortly presented the development of the contactless measuring method on DPEE FEEC BUT in Brno. The last composition of the measuring workstation has good performance for low distance sensing over the rotating part. The measuring probes have small uncertainty of the results and it is comparable with contact measuring method. The contactless measuring method can sense the ferromagnetic material too. The last measurement on big commutator shows the big advantage in time of the measurement against the contact method.

Acknowledgement

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